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# HUNTING FOR THE SELECTRON

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# HUNTING FOR THE SELECTRON[*]

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## ABSTRACT

The cross section for single selectron production in $e^+e^-$ collisions is calculated, and the distribution of its decay $e^\pm$ is given. Observation of this energetic $e^\pm$ would provide the first experimental support for models of low energy supersymmetry; it absence puts a lower limit on the selectron mass in excess of the beam energy.

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There has been considerable renewed interest in models of low energy supersymmetry [1, 2]. In such models the familiar particles of the standard model are accompanied by supersymmetric partners (sparticles) with masses typically less than a few hundred GeV. Experimental constaints on these models come from flavor changing neutral currents [3], cosmology [4] and from the non-observation of any of the supersymmetric partners. In this paper we concentrate on the supersymmetric partner of the electron (selectron).

Squarks and sleptons will be pair produced at $e^+e^-$ colliders when the beam energy exceeds their mass. Being heavy they will rapidly decay into their corresponding quark or lepton and a photino or Goldstino. Such events will have an acoplanar $e^+e^-$ pair carrying approximately 50% of $\sqrt{s}$. These events would be quite clear, and groups at PETRA have been able to set a selectron mass limit of 16.8 GeV [5], very close to the beam energy.[*] A similar limit applies to the smuon and to the stau. This limit on the smuon mass is an improvement on the previous limit from g-2 of the muon. In the supersymmetric limit g-2 vanishes because $\bar{\psi}\sigma^{\mu\nu}\psi F_{\mu\nu}$ is not the highest weight of a superfield [6]. The present experimental value of g-2 for the muon, together with the theoretical uncertainty, implies a lower limit on the smuon mass of 13 GeV [7].

In this letter we point out that selectrons can be produced singly in $e^+e^-$ collisions. Such events would produce a single $e^\pm$ with large transverse energy and large missing transverse momentum, and could be used to probe selectron masses considerably in excess of the beam energy. The process of interest is

$$e^+e^- \to e^\pm \tilde{e}^\mp \lambda \qquad (1)$$

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[*] This limit only applies if the photino decays within the detector.

where $\lambda$ is a photino, and the real selectron $\tilde{e}^{\mp}$ subsequently decays to $e^{\mp}\bar{\lambda}$. To leading logarithm in the beam energy (E) divided by the electron mass (m) the only diagrams which contribute to this process are those in which one of the beam particles radiates a real photon. Since $\ell n\, E/m \gtrsim 10$, this Weizsäcker-Williams approximation [8] is rather good. The $e^{\pm}$ which radiates the real photon is typically scattered by a small angle (75% are within 4° of beam axis) and will not be observed. The cross section in such approximations is usually underestimated by about 25% [9]; contributions from events with off shell photons are ignored. The cross section for producing selectrons of mass M is

$$d\sigma(e^+e^- \to e^{\pm}\lambda\tilde{e}^{\mp}) \simeq \int_x^1 dy F(y)\, d\sigma(\gamma e^{\mp} \to \lambda\tilde{e}^{\mp}) \qquad (2)$$

where $F(y) = \frac{\alpha}{\pi y}\left(1 + (1-y)^2\right)\ell n\, E/m$, $x = \frac{M^2}{4E^2}$ and $yE$ is the energy of the real photon.

Two diagrams (Fig. 1) contribute to $d\sigma(\gamma e^{\mp} \to \lambda\tilde{e}^{\mp})$. In the limit that the photino and electron masses are negligible compared with the beam energy and selectron mass, an analytic formula for the selectron production cross section results from a straightforward calculation:

$$\frac{\sigma(M)}{\sigma_{point}} = \frac{\alpha}{6\pi}\,\ell n\,\frac{E}{m}\left(\frac{2}{x} + 18 - 54x + 34x^2 + 3(3 - 3x - 4x^2)\,\ell nx - 9x\,\ell n^2 x\right) \qquad (3)$$

where $\sigma_{point} = \frac{\pi\alpha^2}{3E^2}$. For E = 20 GeV this gives: $\frac{\sigma(M)}{\sigma_{point}} = 5\%$ for $M = 15$ GeV$(x = .14)$, dropping to $\frac{\sigma(M)}{\sigma_{point}} = .15\%$ for $M = 30$ GeV$(x = .56)$. Since $\ell n\, E/m$ changes slowly with E, these values for a given x are applicable to both present and proposed $e^+e^-$ colliders.

The selectron decays very rapidly to an electron and a photino. The photino lifetime is extremely model dependent. We consider the case where only the electron is observed, and later discuss the effects of photino decays. Experimentally the most important quantity is not the total selectron production cross section, but the differential cross-section for its decay $e^{\pm}$ of energy $E_e$. For the decay $e^{\pm}$ observed at angle $\Omega = \theta,\phi$ to the $e^{\pm}$ beam, we find

$$\frac{d^2\sigma}{dE_e\, d\Omega_e}(e^+e^- \to e^+e^-\lambda\bar{\lambda}) = \frac{\alpha^3}{8\pi E^3}\,\ell n\,\frac{E}{m}\int_x^1 dy\, \frac{1 + (1-y)^2}{y^2 f(y,\theta)}$$

$$\left[2 + \frac{M^2 - A}{yE^2} - \frac{2M^2}{yE^2 A}\left(yE^2 + \frac{M^2}{4}\right)\frac{1}{(1-B)^{1/2}} + \frac{M^4}{A^2}\,\frac{1}{(1-B)^{3/2}}\right] \qquad (4)$$

where

$$A = \left(yE^2 + \frac{M^2}{4}\right)(1 + c') - \sqrt{y}EM^2\,\frac{c'}{E'}$$

$$B = \left(\frac{1 - c'^2}{A^2}\right)\left[\left(yE^2 - \frac{M^2}{4}\right)^2 - \left(yE^2 + \frac{M^2}{4} - \sqrt{y}\,\frac{EM^2}{2E'}\right)^2\right]$$

$$E' = \frac{f(y,\theta)E}{2\sqrt{y}}$$

$$c' = \frac{(1 + y)\cos\theta - (1 - y)}{f(y,\theta)}$$

and $f(y,\theta) = (1 + y) - (1 - y)\cos\theta$. Terms power suppressed by the photino or electron mass have been dropped. If the charge of $e^{\pm}$ is not observed, the cross sections for observing $e^+$ and $e^-$ should be added. This differential cross section, divided by the $\mu$ pair cross section, is plotted against $E_e$(for $\theta = 90°$) and against $\cos\theta$ (for $E_e = 10$ GeV) in Figs. 2 and 3. The integrated forms $\frac{d\sigma}{dE_e}$ and

$\frac{d\sigma}{d\cos\theta}$ are shown in Figures 4 and 5. All plots are for E = 20 GeV. To scale these results for other beam energies both E and M should be scaled by the same factor. In fact, one gains a little extra at higher beam energies from $\ln E/m$.

It is clear from Figs. 2 and 4 that few events of interest are lost by imposing an energy cut on the electron of 40% of the beam energy. This should help to discriminate against background. Although the distribution of $e^\pm$ is slightly peaked in the forward $e^\pm$ direction, the production is not far from isotropic. This reflects the fact that the selectron decays isotropically in its rest frame, and heavy selectrons are produced with low velocities.

A useful limit on the selectron mass from this process requires a sensitivity to these events at the level of 1% of the $\mu$ pair cross section. There is a background from $\tau$ pair production where both $\tau^+$ and $\tau^-$ decay leptonically, and one of the charged leptons is missed. Since the two charged leptons are almost back to back, this source of background should not be serious. If a new heavy lepton of mass $M_L$ exists and experiments are performed with $\frac{M_L}{E} \gtrsim \frac{1}{4}$, then a background from this source will be serious. Other sources of background, such as two photon events or $e^+e^- \to e^+e^-\gamma$, are more difficult to estimate. However such events will tend to have transverse momentum balance.

We stress that although our calculation is not in a particular supersymmetric model, it is applicable only when the photino mass ($\tilde{m}$) is much smaller than the selectron mass: $\tilde{m} \lesssim M/10$. In certain supersymmetric models the photino is the lightest R odd particle, and is consequently absolutely stable (for example, see Reference 10).

In almost all models where the photino is not the lightest R odd particle and is lighter than the selectron, the decay is to a Goldstino and a photon. The lifetime is $\frac{8\pi d^2}{\tilde{m}^5}$ where d is the square of the vacuum energy. d is extremely model dependent: it is probably at least $(250\ \mathrm{GeV})^2$, but can be as large as $(\text{Planck Mass})^2$. Thus $\tilde{m} \sim 100$ MeV corresponds to a decay length of at least a meter, and only the large transverse energy electron will be observed. If either of the photinos decays within the apparatus some of the transverse energy of the lepton will be balanced by a hard photon. This may produce a cleaner experimental signature. Unfortunately, a negative result with such an $e^\pm\gamma$ trigger does not greatly restrict model builders. In contrast, a negative result with an $e^\pm$ trigger will force model builders to increase the selectron mass, or the photino mass. A positive result with either trigger would be tremendously exciting.

We have pointed out that it may be possible to increase the selectron mass limit in $e^+e^-$ collisions from the existing value of 90% of E, to about 125% of E.

## ACKNOWLEDGMENTS

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## REFERENCES

1. P. Fayet, XVI Rencontre de Moriond (1981), First session.

   G. Farrar, Supersymmetry in Nature. Erice Subnuclear Physics 1978: 59.

2. S. Weinberg, HUTP-81/A047 (1981).

   M. Dine and W. Fischler, Phys. Lett. 110B 227 (1982).

   L. Alvarez-Gaumé, M. Claudson and M. B. Wise, HUTP-81/A063 (1981).

   L. Ibanez and G. Ross, Phys. Lett. 110B 215 (1982).

   C. Nappi and B. Ovrut, IAS preprint (1982).

   L. Hall and I. Hinchliffe, Phys. Lett. 112B 351 (1982).

   R. Barbieri, S. Ferrara and D. Nanopoulos, TH.3226-CERN (1982).

3. M. Suzuki, UCB-PTH-82/8 (1982).

   J. Ellis and D. V. Nanopoulos, Phys. Lett. 110B 44 (1982).

4. H. Pagels and J. R. Primack, PRL 48 223 (1982).

   S. Weinberg, PRL 48 1303 (1982).

   N. Cabibbo, G. Farrar and L. Maiani, Phys. Lett. 105B 155 (1981).

   P. Q. Hung and M. Suzuki, Berkeley preprint (1982).

5. Cello Collaboration, H. T. Behrend et al., Contribution to the 1981 Bonn Conference.

   Cello Collaboration, H. T. Behrend et al., DESY 85-021 (1982).

6. S. Ferrara and E. Remiddi, Phys. Lett. 53B 347 (1974).

7. P. Fayet, Phys. Lett. 84B 416 (1979), footnote 4.

8. C. Weizsäcker and E. T. Williams, Z. Physik 88 612 (1934).

9. S. Brodsky, T. Kinoshita and H. Terazawa, Phys. Rev. D4 1532 (1971).

10. S. Dimopoulos and S. Raby, Los Alamos preprint (1982).

## FIGURE CAPTIONS

1. Diagrams contributing to $e^\pm\gamma \to \tilde{e}^\pm\lambda$

   ———————— $e^\pm$
   〰〰〰〰〰 $\gamma$
   - - - - - - - - - $\tilde{e}^\pm$
   ════════ $\lambda$

2. $\frac{1}{\sigma_{point}} \frac{d^2\sigma}{dE_x\, d\cos\theta_x}$ $(e^+e^- \to e^+e^-\lambda\bar{\lambda})$ against $E_x$ for $\theta_x = 90^\circ$.

3. $\frac{1}{\sigma_{point}} \frac{d^2\sigma}{dE_x\, d\cos\theta_x}$ $(e^+e^- \to e^+e^-\lambda\bar{\lambda})$ against $\cos\theta_x$ for $E_x$ = 10 GeV.

4. $\frac{1}{\sigma_{point}} \frac{d\sigma}{dE_x}$ $(e^+e^- \to e^+e^-\lambda\bar{\lambda})$ against $E_x$.

5. $\frac{1}{\sigma_{point}} \frac{d\sigma}{d\cos\theta_x}$ $(e^+e^- \to e^+e^-\lambda\bar{\lambda})$ against $\cos\theta_x$.

Diagrams 2-5 are for a beam energy of 20 GeV, and for various selectron masses M. $\theta_x$ is the angle between the $e^\pm$ beam and the observed $e^\pm$. The cross section is either for $e^+$ observation, or for $e^-$ observation. The μ pair cross section $\sigma_{point} = \frac{\pi\alpha^2}{3E^2}$ has been divided out.

FIGURE 1

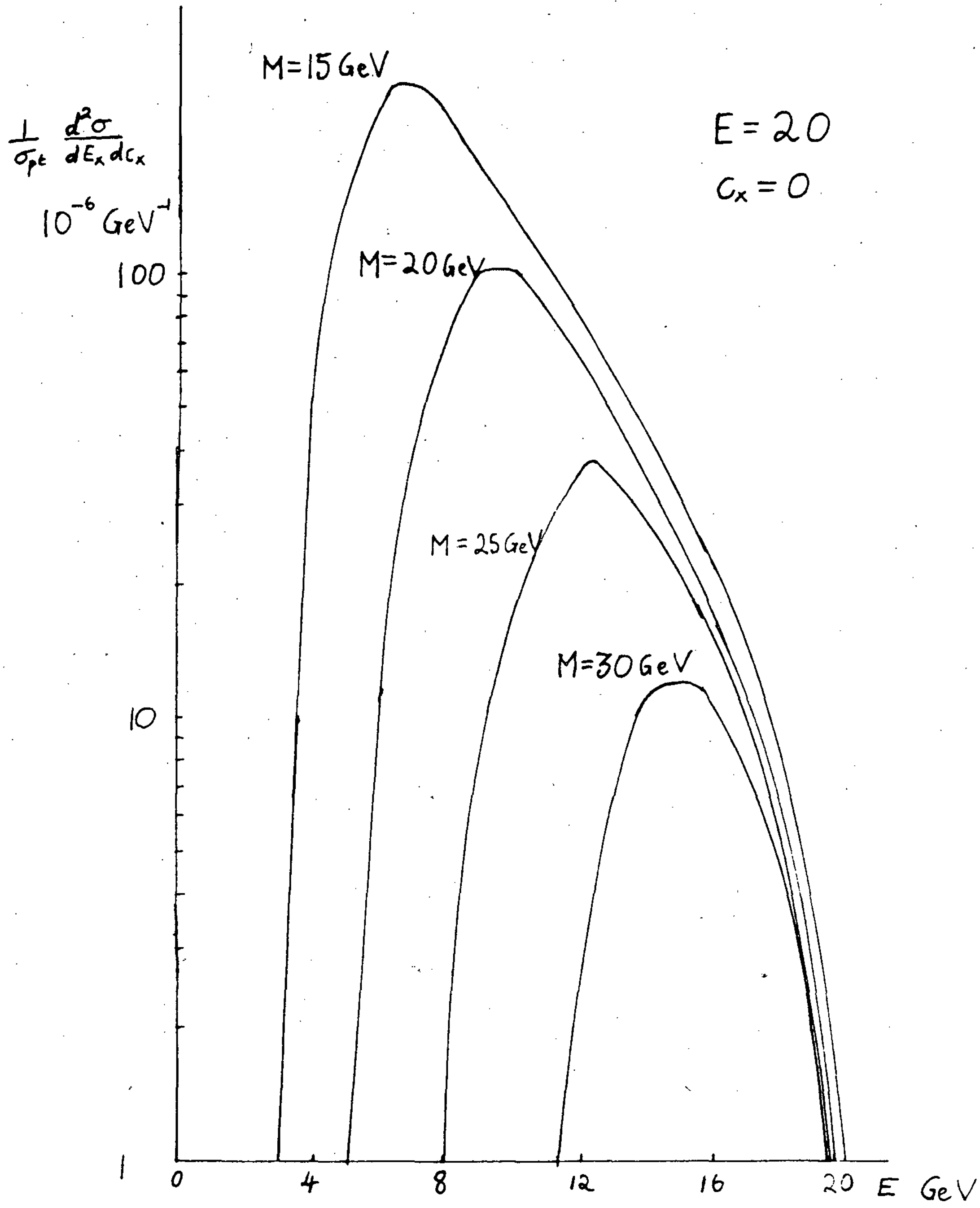
$\frac{1}{\sigma_{pt}} \frac{d^2\sigma}{dE_x dc_x}$
$10^{-6}$ GeV$^{-1}$
100
10
1
M=15 GeV
M=20 GeV
M=25 GeV
M=30 GeV
E=20
$c_x = 0$
0
4
8
12
16
20
E GeV

FIGURE 2

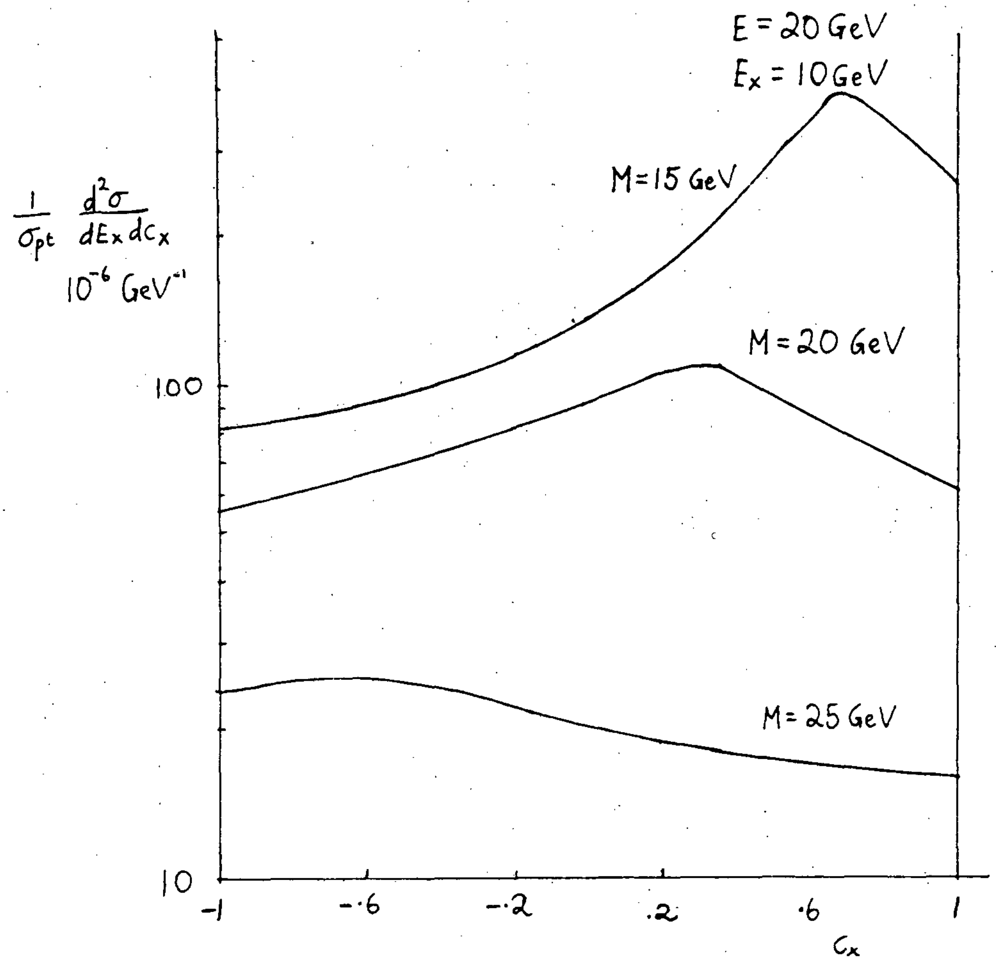
E = 20 GeV
$E_x$ = 10 GeV
M=15 GeV
M=20 GeV
M=25 GeV
$\frac{1}{\sigma_{pt}} \frac{d^2\sigma}{dE_x dc_x}$
$10^{-6}$ GeV$^{-1}$
100
10
-1
-.6
-.2
.2
.6
1
$c_x$

FIGURE 3

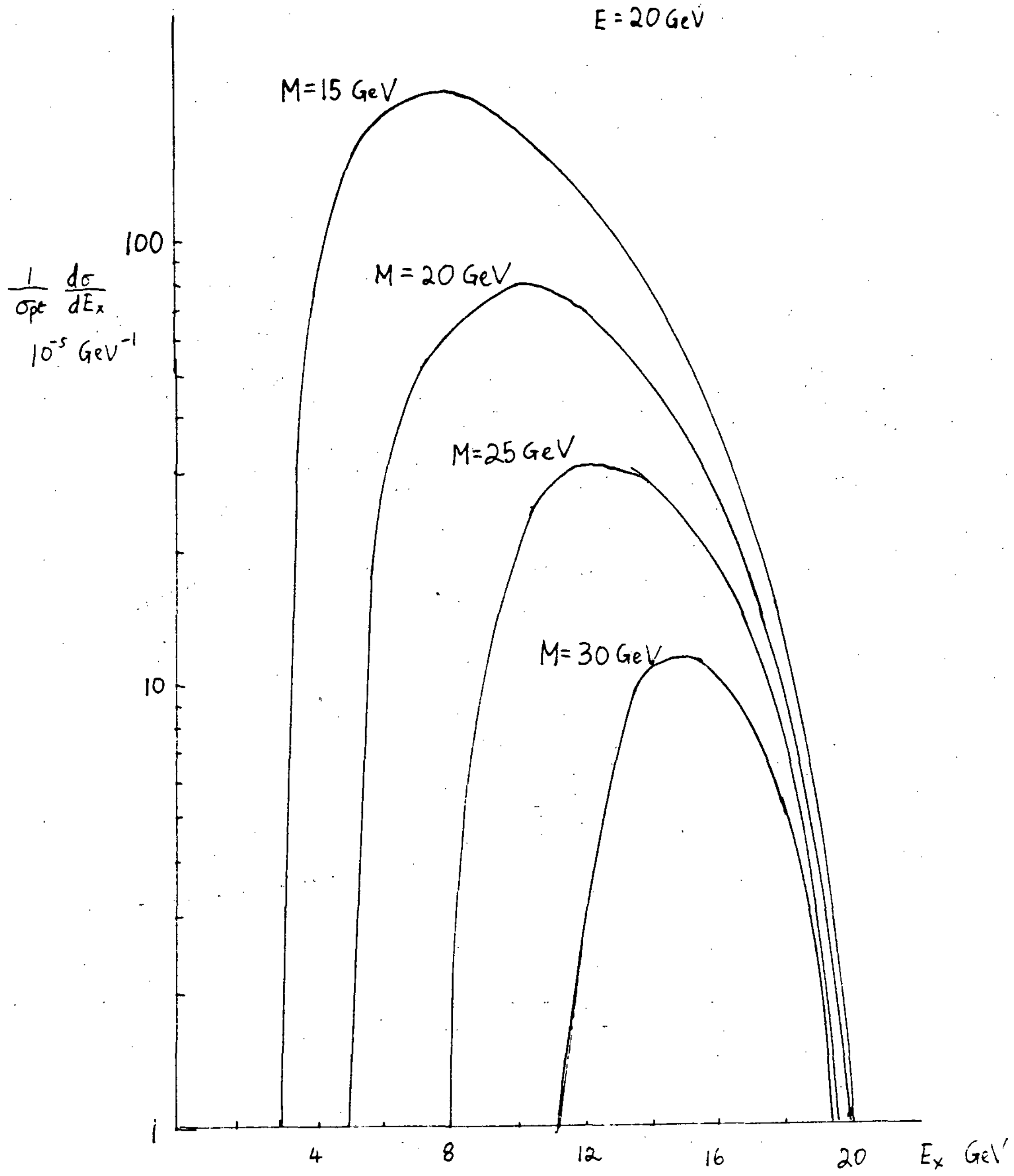
E = 20 GeV
M=15 GeV
M = 20 GeV
M=25 GeV
M= 30 GeV
$\frac{1}{\sigma_{pt}} \frac{d\sigma}{dE_x}$
$10^{-5}$ GeV$^{-1}$
100
10
1
4
8
12
16
20
$E_x$ GeV

FIGURE 4

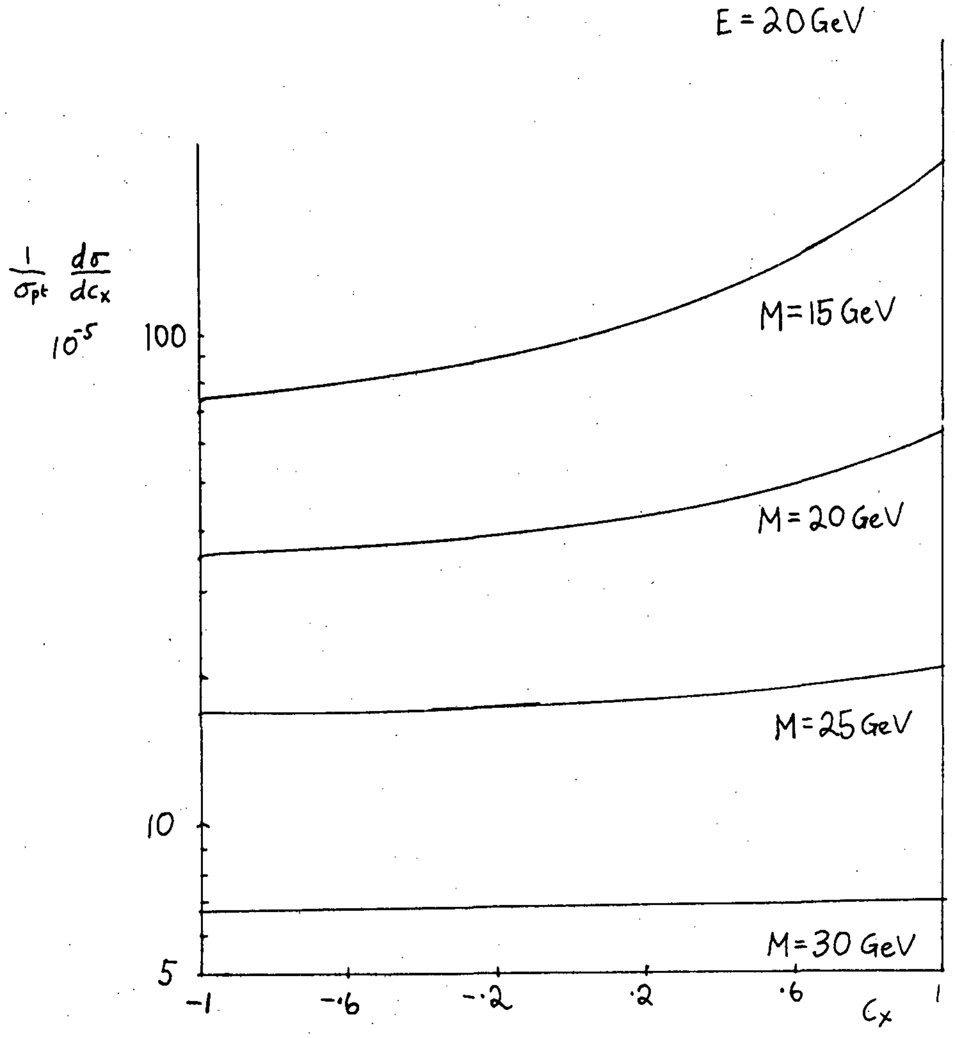
E = 20 GeV
$\frac{1}{\sigma_{pt}} \frac{d\sigma}{dc_x}$
$10^{-5}$
100
10
5
M = 15 GeV
M = 20 GeV
M = 25 GeV
M = 30 GeV
-1
-·6
-·2
·2
·6
1
$c_x$

FIGURE 5

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